Astragalus cobrensis, known only from southwestern New Mexico, is sparingly represented in herbaria, and var. *maguirei* is known only by the type collection. Study of additional material of these forms may prove *maguirei* to be a distinct species.

Echinocereus robustus Peebles, sp. nov.

Echinocereus rectispinus Peebles var. *robustus* Peebles, Amer. Journ. Bot. 25: 675. 1938.

ZOOLOGY.—*The hairworm,* Gordius robustus *Leidy, as a parasite of the Mormon cricket,* Anabrus simplex *Haldeman.*[1] GERALD THORNE, U. S. Bureau of Plant Industry.

INTRODUCTION

Parasites effective against the Mormon cricket, *Anabrus simplex* Haldeman, apparently are very rare. It was, therefore, of considerable interest when there were reports of a heavy parasitism by *Gordius robustus* Leidy in the vicinity of Arrowrock Dam, Idaho (1). Visits to that locality were made by the writer on July 26 and October 9, 1935, and on May 16 and August 24, 1936. The unusual populations occurring there presented excellent opportunities for studying the parasite from the standpoint of life history, habits, host relationship, ecology, and economic importance. Specimens for more detailed examination and experiments were taken to the Salt Lake City, Utah, laboratory.

This observation of *Gordius robustus* coincided with the unprecedented populations of *Anabrus simplex* which first appeared at Fort Hall, Idaho, in May, 1932, and by August, 1936, had infested almost 2,000,000 acres in 24 counties of Idaho (11). Similar outbreaks of the cricket occurred in other western States (Fig. 1).

HISTORICAL

Gordius robustus Leidy, 1851, belongs to the rather common group of organisms known as "hairworms," the adults of which are usually found inhabiting warm shallow pools or streams. In its immature stages it is known as a parasite of certain insects, principally Orthoptera.

The first record of *Gordius robustus* in *Anabrus simplex* (synonym *A. pur-*

[1] The writer is indebted to Claude Wakeland and R. W. Haegele, who gave valued preliminary information on the distribution of *Gordius robustus* in the Arrowrock section and joined in visiting the area on two occasions. J. Percy Moore, of the University of Pennsylvania, kindly lent the Leidy collection of *G. robustus* from Milk River, Mont., and Dr. Henry B. Ward forwarded the May collection from Urbana, Ill., for comparison with the Idaho and western Montana specimens collected in 1935. G. Steiner and Edna M. Buhrer have given valuable suggestions on the manuscript and bibliography. The map used in Fig. 1, giving the 1937 distribution of *Anabrus simplex*, is taken from a U. S. Department of Agriculture Press Service release, March 26, 1937. Received November 18, 1939.

purascens[2]) is given by Riley, Packard, and Thomas (9, footnote 83, p. 327), who mention "*Gordius robustus*, Leidy.—A ♂ from ♀ *Anabrus purpurascens* Uhler; in Mr. Riley's cabinet." No records remain as to the locality in which this specimen was collected. Riley, Packard, and Thomas (10, p. 64) quote Bruner's remarks on parasites of the Mormon crickets observed along the Portneuf River, Idaho: "Hair-worms (*Gordius*), too, are frequently found wound about their intestines."

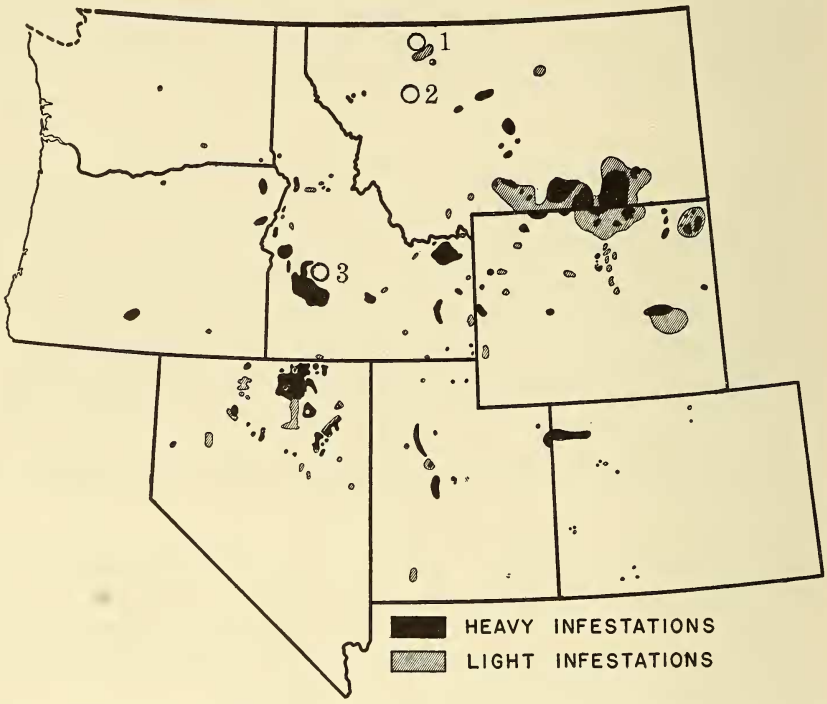

Fig. 1.—Range of *Anabrus simplex* in 1937 and known distribution of *Gordius robustus:* 1, Cutbank, Mont.; 2, Augusta, Mont.; 3, Arrowrock Reservoir, Idaho.

Leidy (3) reported *Gordius robustus* from New Jersey as a parasite of a grasshopper, later (5) identified as *Conocephalus fasciatus fasciatus* (DeGeer) (synonym *Orchelimum gracile* Harris), and (4) of the carabid beetle *Pterostichus* (*Gastrellarius*) *honestus* Say (synonym *Pterostichus fastiditus* Dej.). Thomas (9) found a female in *Stenopalmatus fuscus* Haldeman (synonym *S. fasciatus* Thomas) at Wasatch, Utah. May (6) reports it in the vicinity of Urbana, Ill., as a frequent parasite of *Orchelimum vulgare* Harris, *O. nigripes* Scudder, *Conocephalus memoralis* (Scudder) (synonym *Xiphidium nemorale* Scudder), and occasionally *Phaneroptera furcata furcata* (Brunner) (synonym *Scudderia furcata* Brunner).

[2] Synonyms given are the host names of the original records.

THE IDENTITY OF GORDIUS ROBUSTUS LEIDY, 1851

The type specimen of *Gordius robustus* from *Concocephalus fasciatus fasciatus* has not been preserved, but a collection from Milk River, Mont., made in 1876 and identified by Leidy, is still available. This consists of four males and six females varying from 31 to 46 cm in length. The hosts of these specimens are unknown, but they were collected within the range of *Anabrus simplex* and, judged from their size, it appears quite probable that they grew in these large insects. These 10 specimens are identical to those recently collected in Idaho and Montana except for their lighter color, which is due to bleaching during their long preservation in alcohol.

Leidy's original designation of the name *Gordius robustus* was given with a very meager description (3). Later (4, p. 57) he published a more detailed description but listed the species as a synonym of *G. aquaticus?* Gmelin (which is *G. aquaticus* Linn., 1758). He followed the name with a question mark, indicating that his specific designation was questionable. Montgomery (7) placed the species as a variety, *G. aquaticus robustus;* but later (8) made it a synonym of *G. villoti* Rosa, 1882. May (6) considered *G. robustus* as a valid species and prepared an excellent, detailed morphological description.

After examining the specimens from Milk River, Mont., the writer considers that May's action was fully justified. To further establish the fact, specimens from the Arrowrock section were sent to Kurt Heinze, a leading European authority on Gordioidea, who pronounced them as being neither *Gordius aquaticus* nor *G. villoti.*[3] Caballero (2) records both *G. robustus* and *G. aquaticus* from Mexico, thus supplying additional evidence that the two species are distinct.

Since Leidy determined the specimens from Milk River, Mont., as being the same as his type specimen of *Gordius robustus* from New Jersey and also in view of the fact that May found the species prevalent in Illinois, the writer has no basis for assigning the form to any other species.

DISTRIBUTION OF GORDIUS ROBUSTUS AS A PARASITE OF ANABRUS SIMPLEX

A survey of the Arrowrock section on July 26, 1935 (Fig. 2), revealed that there was a great difference in the number of *Gordius* present in the various localities. They were most numerous on Elk Creek where tangled masses (Fig. 3) were present in almost every pool, and many more were scattered along the stream or buried in the loose gravelly soil or under rubbish. At Grouse Creek and near Long Gulch Ranger Station they were almost as numerous, while small numbers were present in Slide Gulch, Cottonwood, Highland Valley, and other points along the route.

After the first reports of the parasitism of Mormon crickets by a *Gordius,* workers in the various cricket infested areas of the Western States were on the alert for additional localities in which the hairworm might be present.

[3] Personal communication dated February 20, 1937.

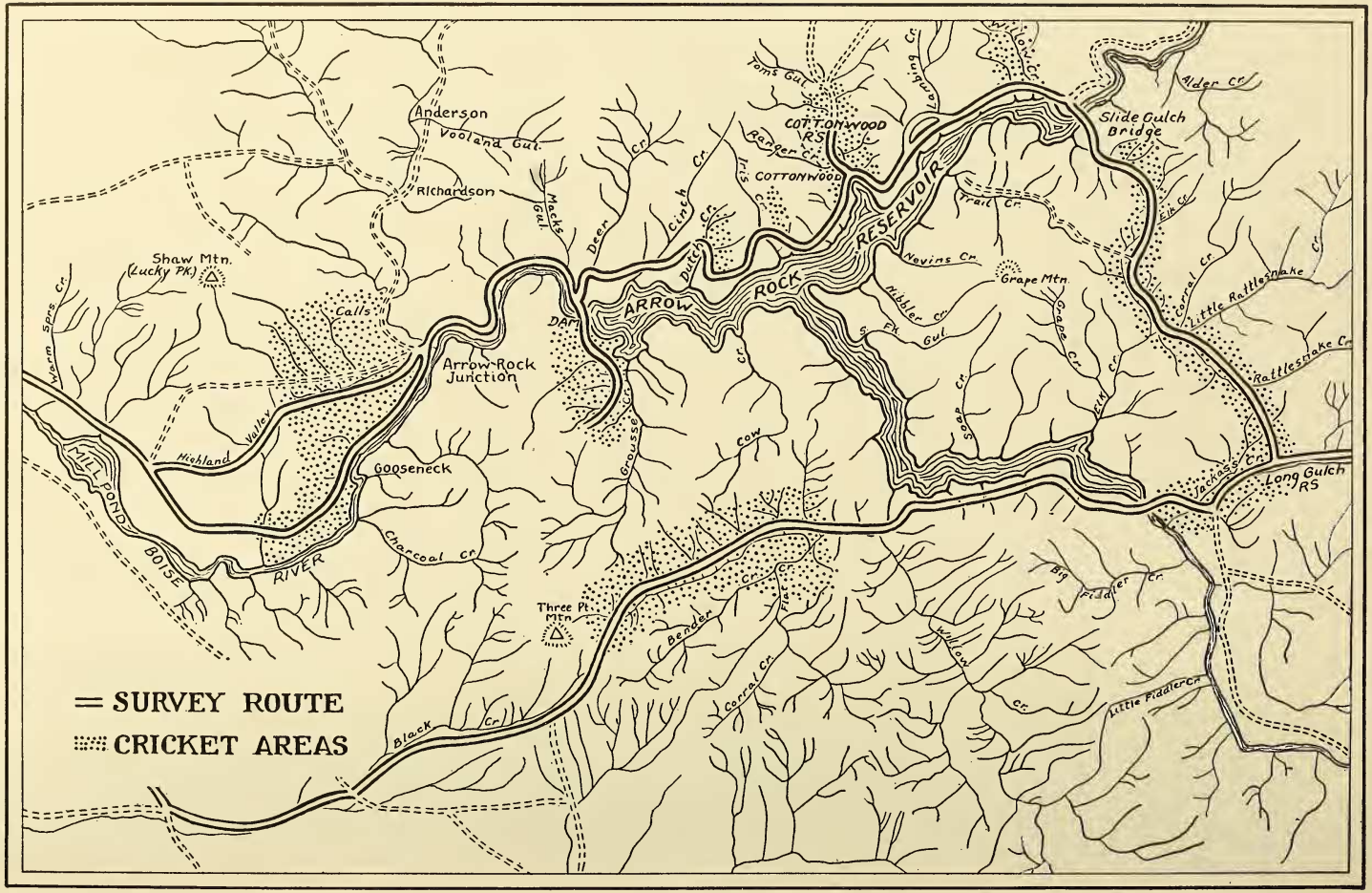

Fig. 2.—The Arrowrock Reservoir section showing survey route, July 26, 1935, and location of Mormon-cricket bands at that time.

However, the only places added were in Montana, where Frank Cowan and Horace J. Shipman, of the U. S. Bureau of Entomology and Plant Quarantine, collected a considerable number near Cutbank and a single female near Augusta (Fig. 1).

ECONOMIC IMPORTANCE OF GORDIUS ROBUSTUS

Reliable reports indicate that between 25 and 50 percent of the Mormon crickets invading the Grouse Creek section early in July 1935, were parasitized by *Gordius robustus*, and this appeared to be corroborated by the great numbers present in the stream and buried in wet areas. At that time on Arrowrock Reservoir the crickets entered the water in great numbers, until patches 2 or 3 square rods in extent sometimes were floating about and from them large numbers of Gordii emerged and congregated along the shore. By July 26 it was evident that the larger portion had left their hosts, and it was difficult to find crickets in which Gordii still remained; between Arrowrock Dam and Grouse Creek only five parasitized crickets were found among 1,000 examined, and in other localities they were just as rare. However, the

Fig. 3.—Entangled mass of *Gordius robustus* collected on upper Elk Creek.

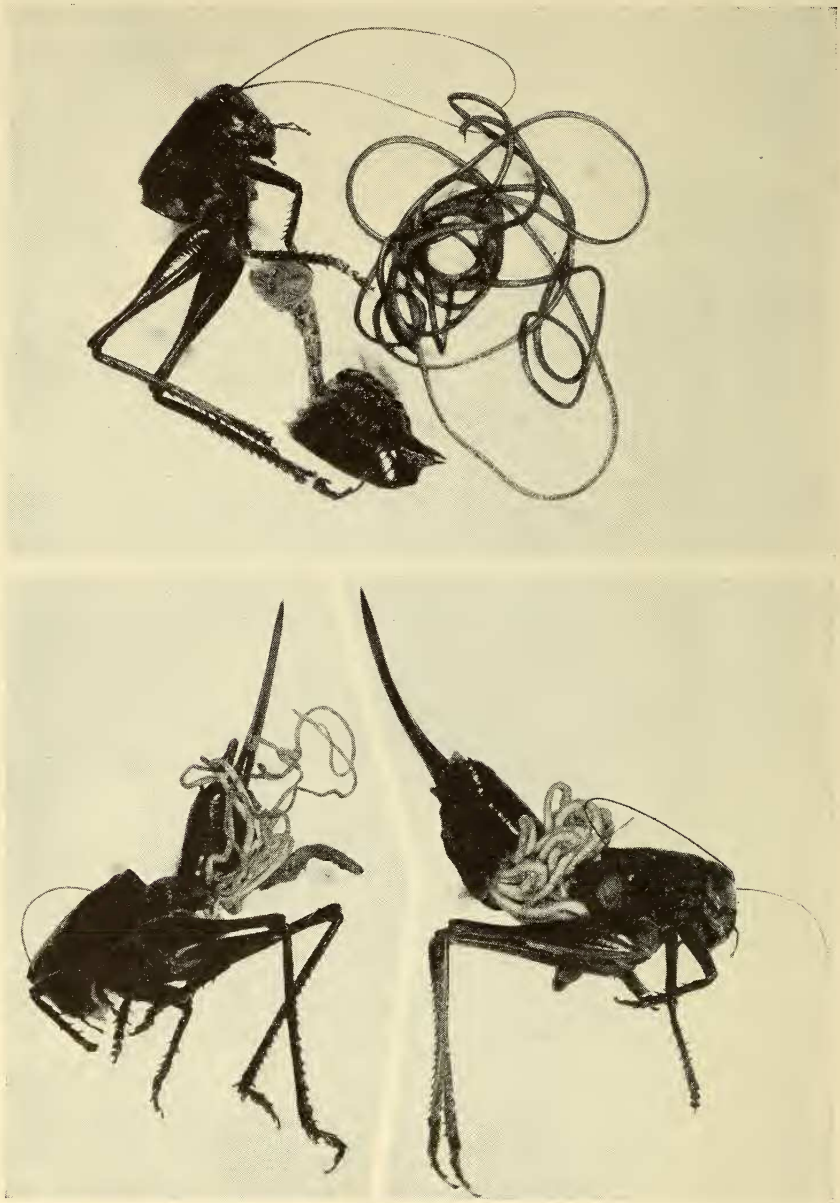

FIG. 4.—*Anabrus simplex* parasitized by *Gordius robustus*. Note in the top figure how thoroughly the body contents of the insect have been absorbed, leaving only the alimentary canal. Natural size.

crickets are migratory, remaining in one locality only a short time, and it is probable that those observed by the writer were from different breeding areas than those in the earlier invasions.

Commenting on the parasitized crickets collected on September 26, 1935,

near Cutbank, Mont., Horace J. Shipman wrote, "The parasitized crickets were found near a pond, which was the only one in the vicinity. Crickets taken within 100 yards of the pond were approximately 99 percent parasitized, and only one of the crickets contained eggs. One mile north of this pond the crickets were about 50 percent parasitized."[4]

On July 20, 1936, Claude Wakeland[5] reported that about one-fourth of the crickets in the Slide Gulch and Rattlesnake localities near Arrowrock Reservoir were parasitized.

None of the parasitized crickets collected by the writer contained eggs. The body cavity was invariably found to be completely filled with the parasite, and only the alimentary canal remained (Fig. 4). The parasitized female containing a few eggs reported above by Shipman may have been a case of very late parasitism after the ovaries had been developed.

It is evident that female crickets parasitized by *Gordius robustus* rarely produce eggs; therefore, in regions of heavy parasitism the cricket population must be considerably reduced. Since only a minor portion of the breeding grounds of the Mormon cricket lies near streams, ponds, and swamps suitable for the propagation of *Gordius*, the effective control exercised over the total cricket population during extensive outbreaks probably is negligible. The migratory habits of the cricket bring great numbers to streams where they may become parasitized but at the same time a large portion of these individuals wander far from water and die, the parasites being lost because water is essential to completion of their life cycle.

During the many years between extensive cricket outbreaks only small bands occur, and these generally are confined to the higher elevations where there is more abundant moisture. In those regions where *Gordius* is abundant the water-frequenting habits of the crickets no doubt bring practically all of them in contact with *Gordius*, and during such periods it seems quite probable that economically more effective parasitism occurs.

MORPHOLOGY OF GORDIUS ROBUSTUS

Adults.—But little can be added to May's description of the adults (6). The specimens observed all correspond closely with his observations except in minor points, which apparently are due to individual variation. Very light-colored specimens, especially females, apparently lack the dark dorsal and ventral bands and light-colored areas of the cuticle that May mentions, but they show distinctly on all the darker-colored females and males. These markings were also absent on the bleached, alcohol-preserved specimens from the Leidy collection. The branching hairs of the cuticle mentioned by Montgomery (7) could not be found, and since May also failed to observe them this statement must have been an error. Considerable variation in the male postcloacal ridge occurred among the specimens collected,

[4] Personal communication dated December 9, 1935.
[5] Personal communication dated June 20, 1936.

the most common form being slightly angular (Fig. 5, A), while a more angular type (Fig. 5, B) was comparatively rare.

The oral opening is degenerated to a minute scar (Fig. 5, C), which is visible only in a face view. In no instance was it observed that the larval spear remained within the oral aperture.

A brownish ring generally surrounds the cloacal opening of the female, but on occasional specimens it is entirely lacking. When present it varies considerably in its distinctness and width.

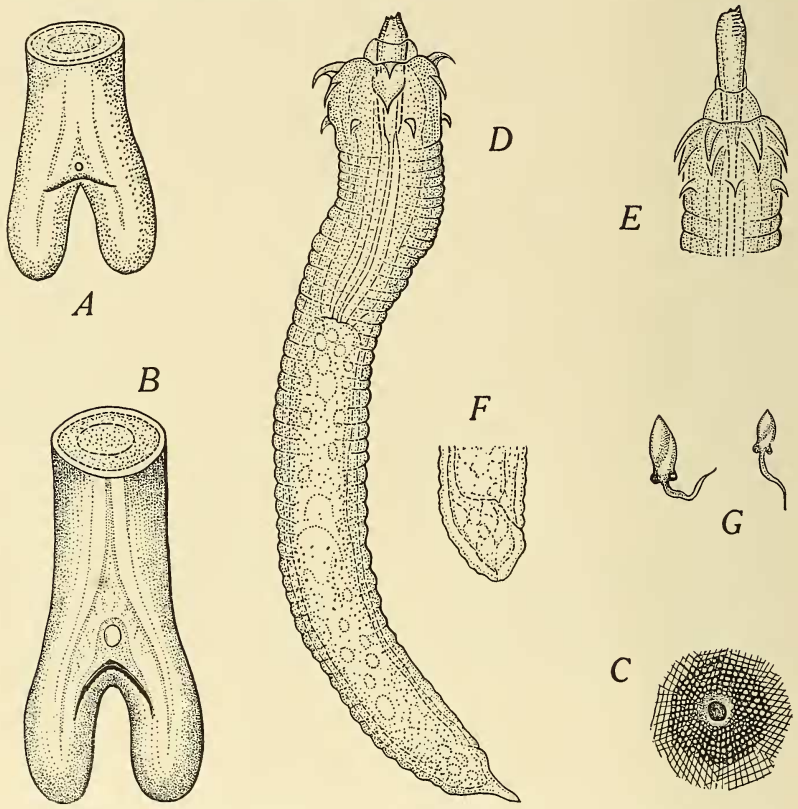

Fig. 5.—A, B, Male tails showing variations in the form of the cloacal ridge, ×25. C, Rudimentary oral opening, ×750. D, Larva, ×750. E, Head of larva with protruded proboscis, ×750. F, Posterior portion of larva with blunt terminus, ×750. G, Sperms, ×1500.

Specimens of *Gordius robustus* from *Anabrus simplex* frequently are very large. Wakeland and Shull (11) state that they reach a length of 48 inches (121.9 cm), and the writer collected a female 120.6 cm long. A random collection of 200 specimens contained 63 females varying in length from 13 cm to 120 cm and 137 males from 18 cm to 91 cm.

Eggs.—The slightly ovate eggs average about 38μ wide by 51μ long and are deposited in slender broken cords held together by a gelatinous mucus,

which swells on contact with water until the egg cord is about 1 mm in diameter (Fig. 6, A). The ovary occupies almost the entire body cavity, and the number of eggs produced by a female is enormous, those from a 106-cm female being estimated at 28,902,500. There is a short uterus, 2 to 3 mm long, in which huge numbers of minute spermatozoa (Fig. 4, G) can be found in fertilized females. The body of the spermatozoon appears to be somewhat flattened and concave, probably giving it a rotary motion as it is propelled by its tail. Fertilization of the eggs occurs as they pass through the uterus.

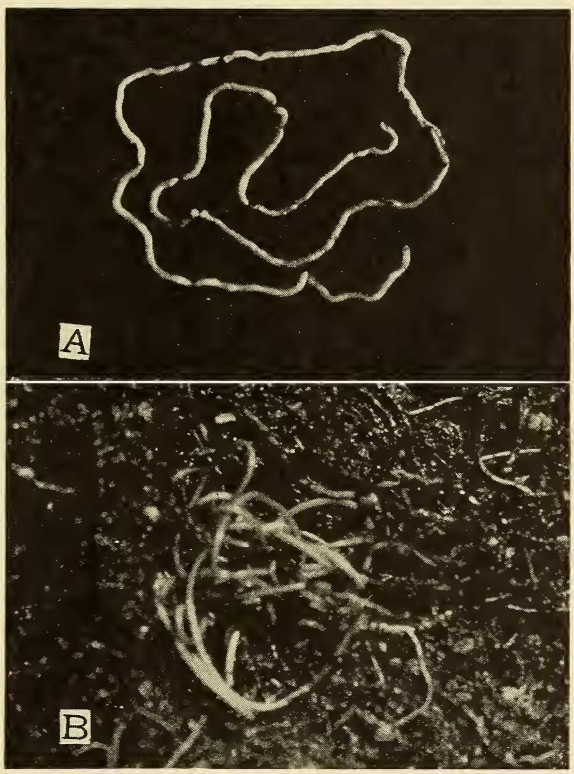

Fig. 6.—A, Egg cord after deposition, ×1.
B, Female hibernating among roots, ×1.

Eggs are regularly deposited in spring, but rare females occasionally were observed depositing in fall. Segmentation and larval development may occur immediately or be delayed for some months.

LIFE CYCLE OF GORDIUS ROBUSTUS IN THE ARROWROCK SECTION

Overwintering females emerge from their hibernating quarters in the loose gravelly soil or under sticks, stones, and rubbish (Fig. 6, B) during April and May and enter the shallow water of swamps, pools, or streams where the eggs are deposited. Many of the eggs hatch soon after deposition,

while others may remain for several months without hatching. Some of these taken to Salt Lake City contained living larvae until September, and it is doubtful if they would have hatched that fall.

The minute larvae move slowly about in the water, frequently lifting themselves up on the tips of their tails and swinging about in circles. Here they apparently are picked up by the young crickets when drinking, or when eating aquatic plants, and pass to the intestine. Presumably they force their way through the intestinal wall into the body cavity with the toothed proboscis while they cling to the intestinal tissues by means of the three rows of cephalic hooks.

After entering the body cavity growth takes place so rapidly that by late in June many are full grown and ready to emerge from the crickets. Apparently the time of leaving the host depends upon some sense of proximity to water, for during the heat of the day, when crickets congregate in the shade along streams or moist areas, the mature *Gordius* break through the abdominal wall and emerge, moving into the water or burying themselves in the moist soil.

At the time of emergence from the host the color of the females varies from a milky white to light brown, and that of the males from light to dark brown. After exposure to light the color deepens, especially in the males, which are usually darker than the females, sometimes almost black.

Copulation takes place in the water, perhaps also in the soil, soon after emergence. Females collected July 26 usually contained sperms in the uterus.

Larvae.—The larvae (Fig. 5, D) range in length from 0.12 to 0.16 mm and average about one-ninth as wide as long. The flexible cuticle is marked by annules that vary in distinctness and width as the individual moves about. The broad anterior end bears three circlets of cephalic hooks, the second row is arranged directly behind the first, while the third row alternates, the hooks being back of the interspaces of the first two rows. When at rest these hooks are retracted into the oral opening until the last row points almost straight forward. As the proboscis is extruded the hooks roll out and back (Fig. 5, E).

The slightly clavate proboscis bears two or three very minute projections on its distal end. Back of these, on the anterior conoid portion, are about six rows of fine corrugations. The proboscis joins the tubular esophagus, their combined length varying from one-eighth to two-fifths that of the entire body.

The larvae generally have a pointed tail, but occasional specimens had blunt, rounded tails (Fig. 5, F).

The larvae are soft bodied and unable to withstand drying. Exposure to air on a bamboo splinter for one minute was fatal in every case.

The manner in which the larvae of *Gordius robustus* enter *Anabrus simplex* was determined by the following method: A supply of crickets was secured near Tooele, Utah, where *G. robustus* is not known to occur. Lettuce was fed to the crickets, and as soon as one was busily feeding a drop of water con-

taining several larvae of *G. robustus* was placed just in front of it. Generally the cricket continued feeding and swallowed the larvae along with the food.

Thirty crickets were fed in this manner on June 15 to 18 and placed in a cage. A few crickets were removed each week thereafter, three to five at a time, and dissected. On July 1, one female contained a male *Gordius* 260 mm long and on July 9 another female was found with a male *Gordius* 245 mm long. Of the 30 crickets, 18 died and 12 were dissected. Only the two mentioned were parasitized.

At the same time 23 crickets were selected, and a drop of water containing several larval *Gordius* was placed in the folds between the sclerites of the abdomen. Of these 23 crickets, 9 died and the remainder were dissected, none being found infested. Because of their sensitiveness to drying it would appear impossible for the larvae to enter the body of the host in any manner other than through the mouth.

Unfortunately the season was so far advanced that very young crickets could not be secured, and those used in the above experiments were all in the second and third instars. In these large crickets the larval *Gordius* apparently are carried through the intestinal tract before they have an opportunity to penetrate the intestinal wall. This appeared to be proved by the fact that among 50 adult crickets confined in wet swampy pens, in which thousands of *Gordius* eggs and larvae were kept in excellent condition, not one became parasitized. An abundance of small aquatic plants was present and these, together with the water consumed, certainly would appear to have given every cricket ample opportunity to become parasitized.

ECOLOGICAL FACTORS

In the postparasitic stages *Gordius robustus* thrives best in warm shallow pools with loose gravelly banks well covered with vegetation. These conditions enable them to congregate during the mating season and later work their way into the loose soil, under stones and sticks, or into masses of roots or leaves, where they hibernate during winter. Seep areas where warm ground water rises during winter are especially favorable, and in the Arrowrock Dam section these areas were generally inhabited by large numbers.

In the years preceding these investigations such conditions had prevailed in the Arrowrock section. There had been no unusual runoff and the stream beds were littered with sticks, pieces of logs, and loose stones, making ideal breeding conditions for *Gordius robustus* (Fig. 7, A).

The months of January and February, 1936, were unusually cold, each with average mean temperatures of 23.4° F., 1.7° and 7.4° respectively below the normal at the Arrowrock Reservoir station. This temperature was accompanied by a heavy snowfall with a water content of 10.14 inches, 4.87 inches above the mean for these two months. As a result the loosely packed snow melted rapidly during March and especially during April. Streams flooded over their banks, channels were widened and deepened, and all

Fig. 7.—A, Upper Elk Creek, Idaho, July 26, 1935.
B, Same location, May 16, 1936.

debris was removed (Fig. 7, B). Most of the hairworms that had hibernated in the stream channels and adjacent banks were carried away by these floods. Scores of them could be found hanging high on limbs and roots where they had been left as the waters receded. As a result the *Gordius* population in the Elk Creek and neighboring basins was estimated to be

only 5 to 10 percent as great as in the preceding year. Many years will be required to repair the erosion damage to these stream beds and return them to their former conditions, which were so favorable as breeding grounds for *Gordius*.

SUMMARY

The hairworm *Gordius robustus* was first observed as an important parasite of the Mormon cricket, *Anabrus simplex*, in 1935 in the vicinity of Arrowrock Reservoir, Idaho. In certain localities of this area there are favorable breeding grounds for the hairworm along small mountain streams and in pools or swamps. In these localities they may be of economic importance in the control of ordinary populations of Mormon crickets. However, during heavy outbreaks of crickets, such as occurred in 1935 to 1937, the percentage of parasitism was too small to be of economic importance, although in some instances it reached 25 to 50 percent of the crickets. Similar parasitism was also observed near Augusta and Cutbank, Mont., where in certain small areas 50 to 99 percent of the crickets contained Gordii.

Parasitized crickets rarely produce eggs. They live normally until the mature *Gordius* breaks through the abdominal wall and enters water or wet soil. Here the Gordii mate and later hibernate in moist places under sticks and stones or among roots and rubbish. Some eggs are deposited in fall but more generally in spring, when the females emerge from hibernation and deposit them along the shores of streams, ponds, or swampy areas. Here the minute larvae hatch and probably are picked up by the young crickets when drinking water or eating aquatic vegetation. Upon reaching the intestine of the cricket they apparently bore through the wall and enter the body cavity, remaining there until maturity.

Under present erosion conditions in breeding areas of the *Gordius* most of them are carried away by floods.

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